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Khodr

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(54) **RESILIENT BUMPER AND BUMPER SYSTEM**

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USPC 267/193
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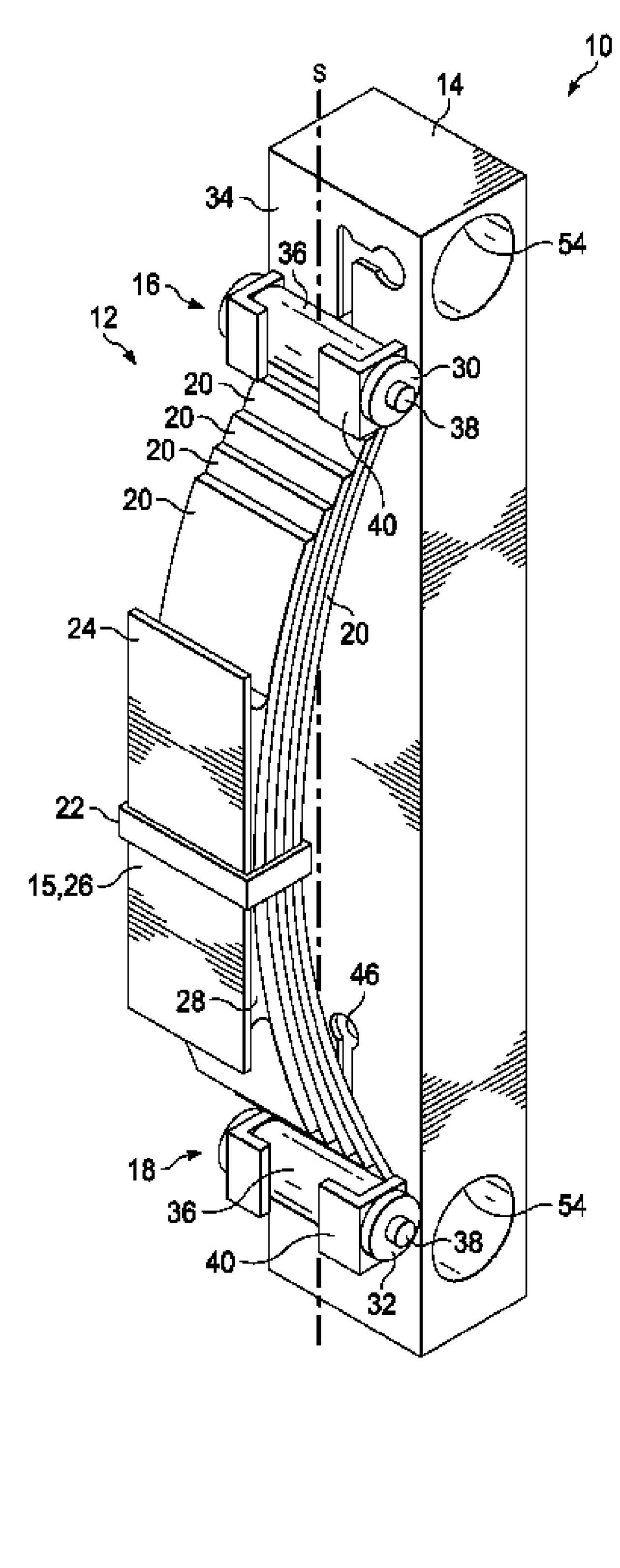
(57) **ABSTRACT**

The present disclosure describes a resilient bumper that comprises an arc-shaped spring member that extends from a first end to a second end along a spring axis and includes an impact surface arranged between the first and second ends; and a support member that includes an attachment interface that extends in parallel to the spring axis of the spring member and is configured to releasably engage the first and second ends of the spring member. A bumper system and a marine structure are also described.

17 Claims, 9 Drawing Sheets



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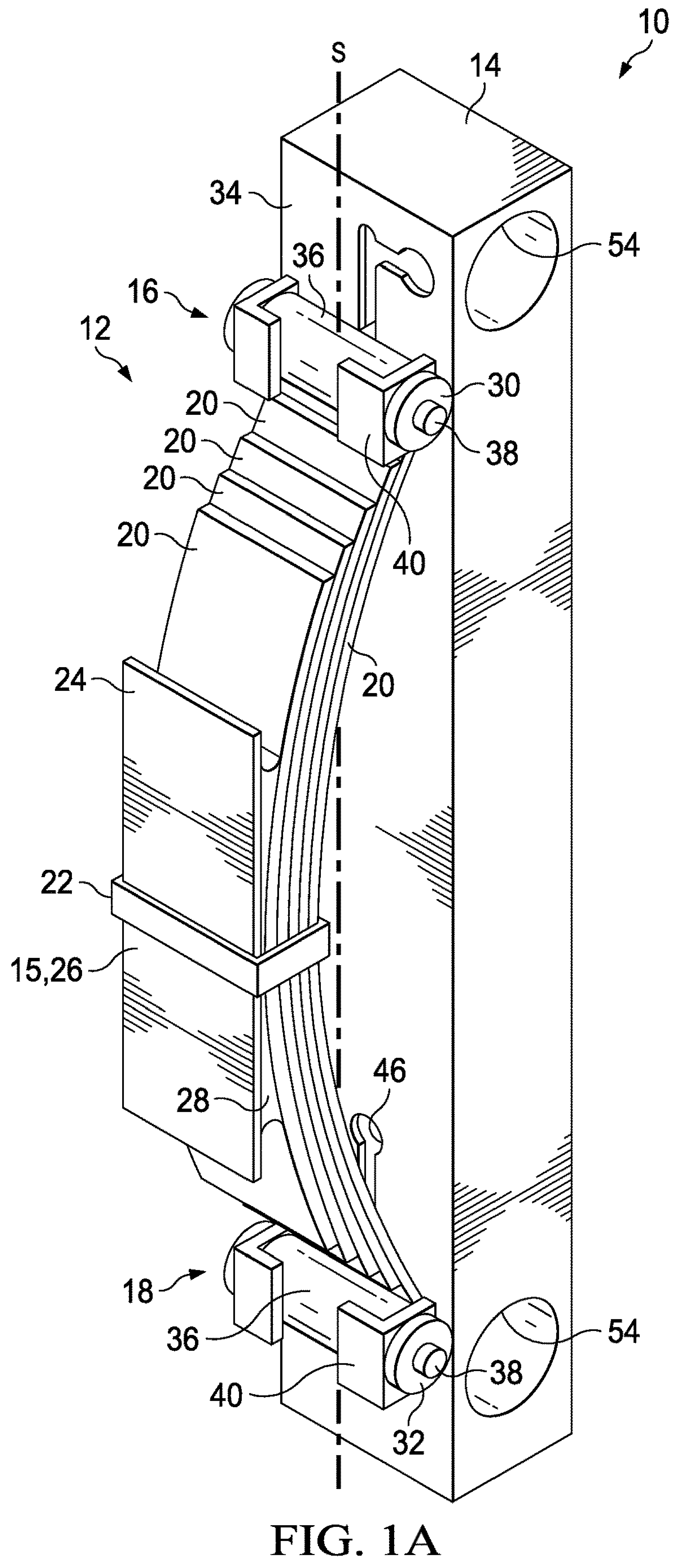
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FIG. 1A

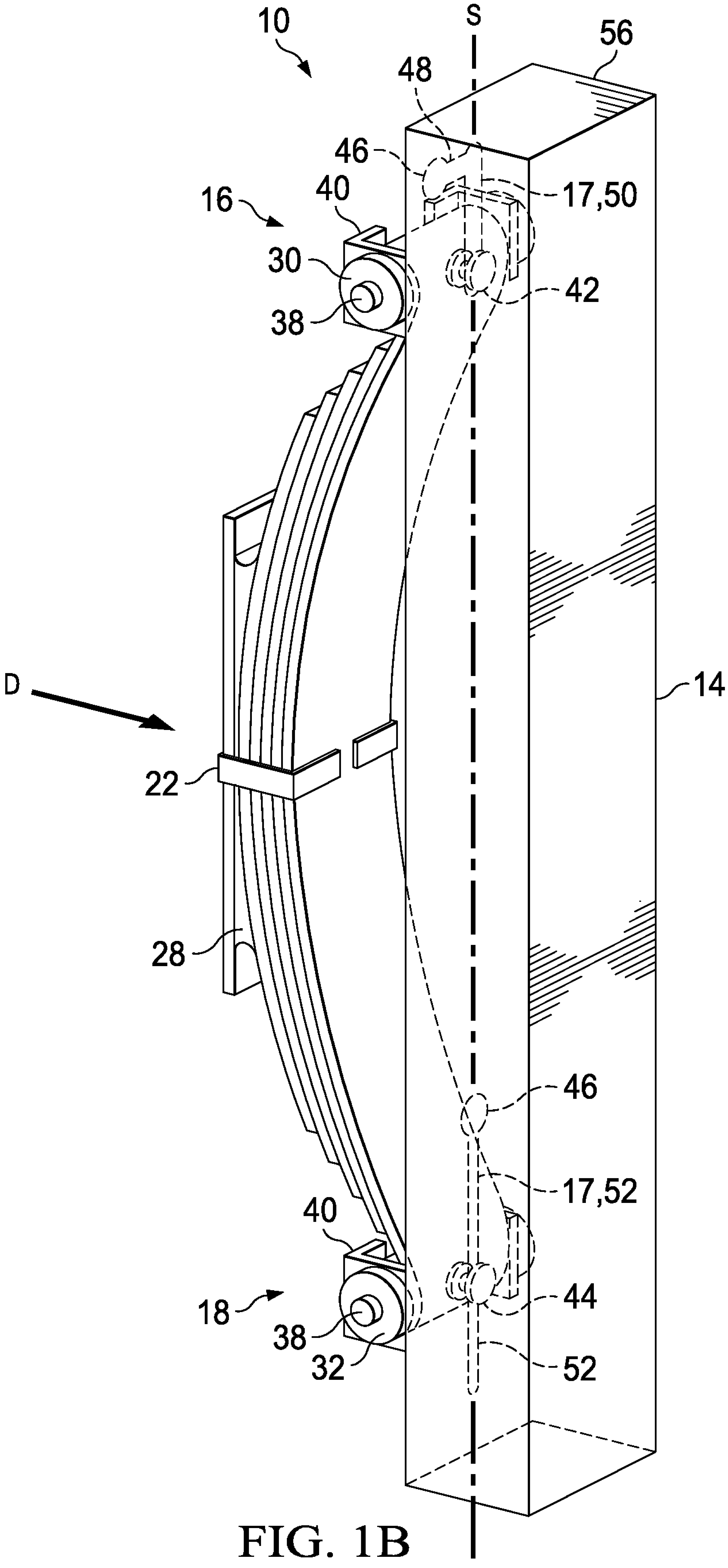

FIG. 1B

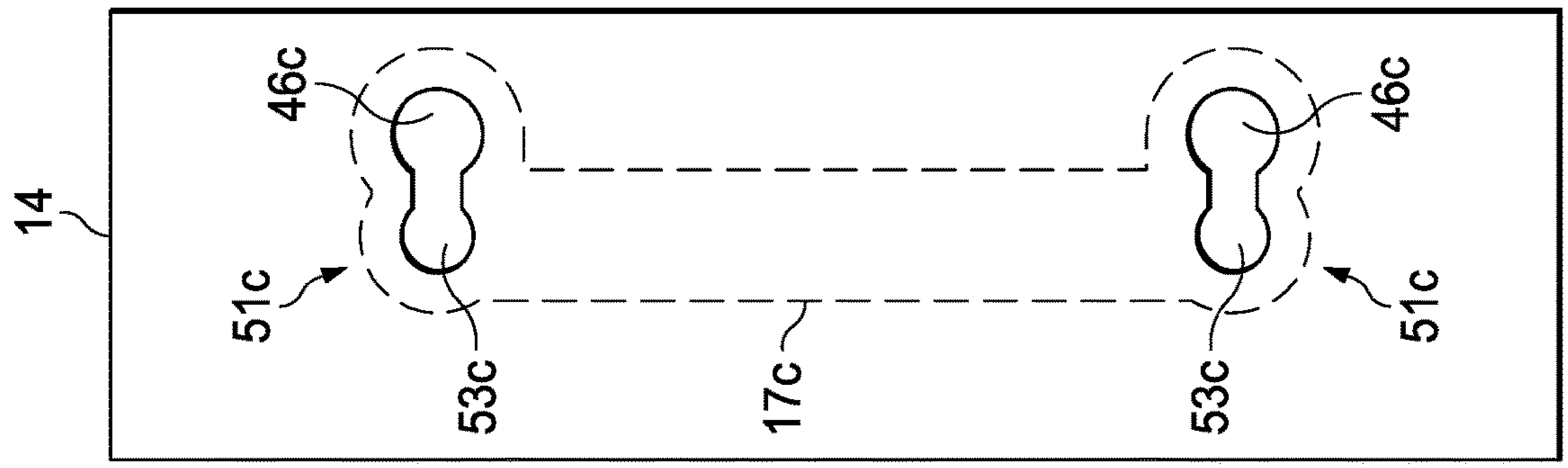

FIG. 2C

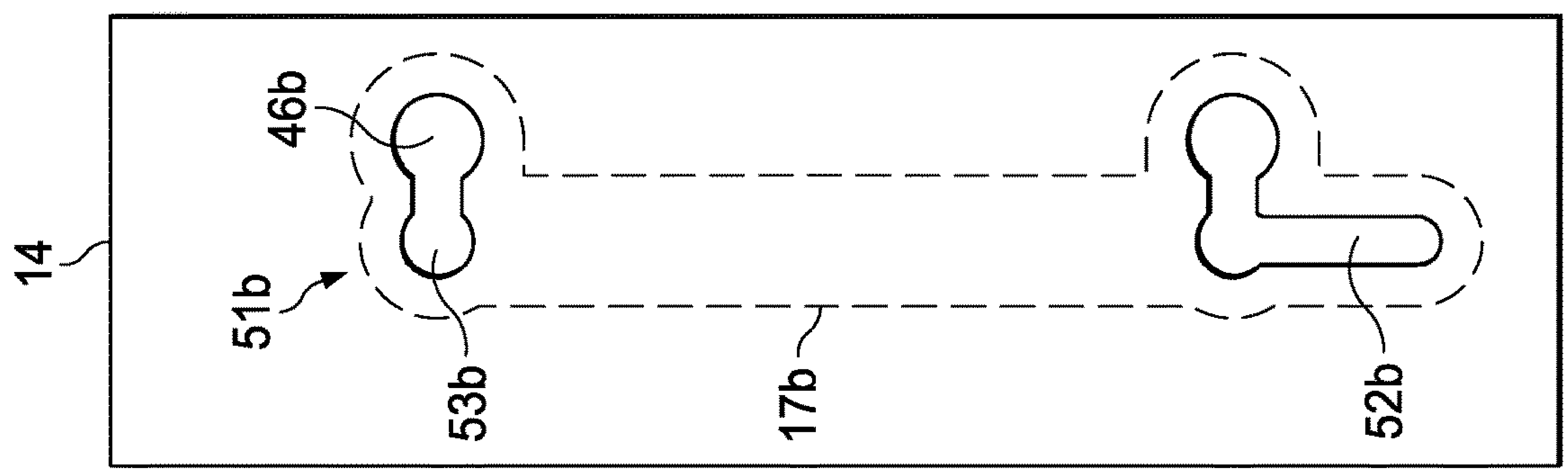

FIG. 2B

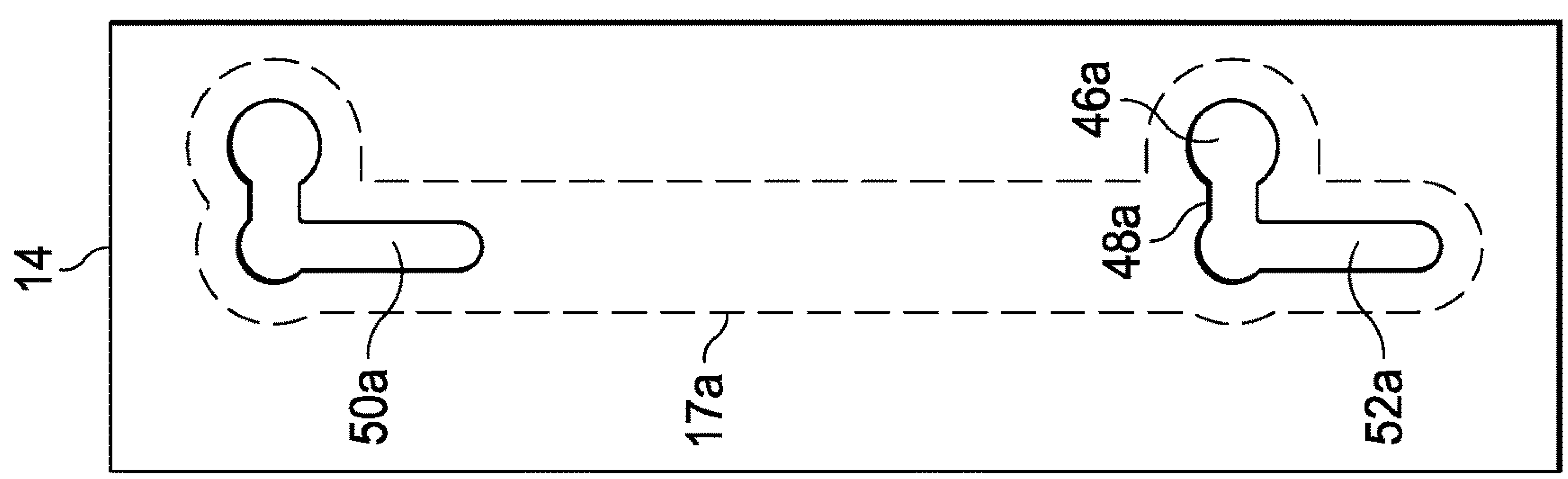

FIG. 2A

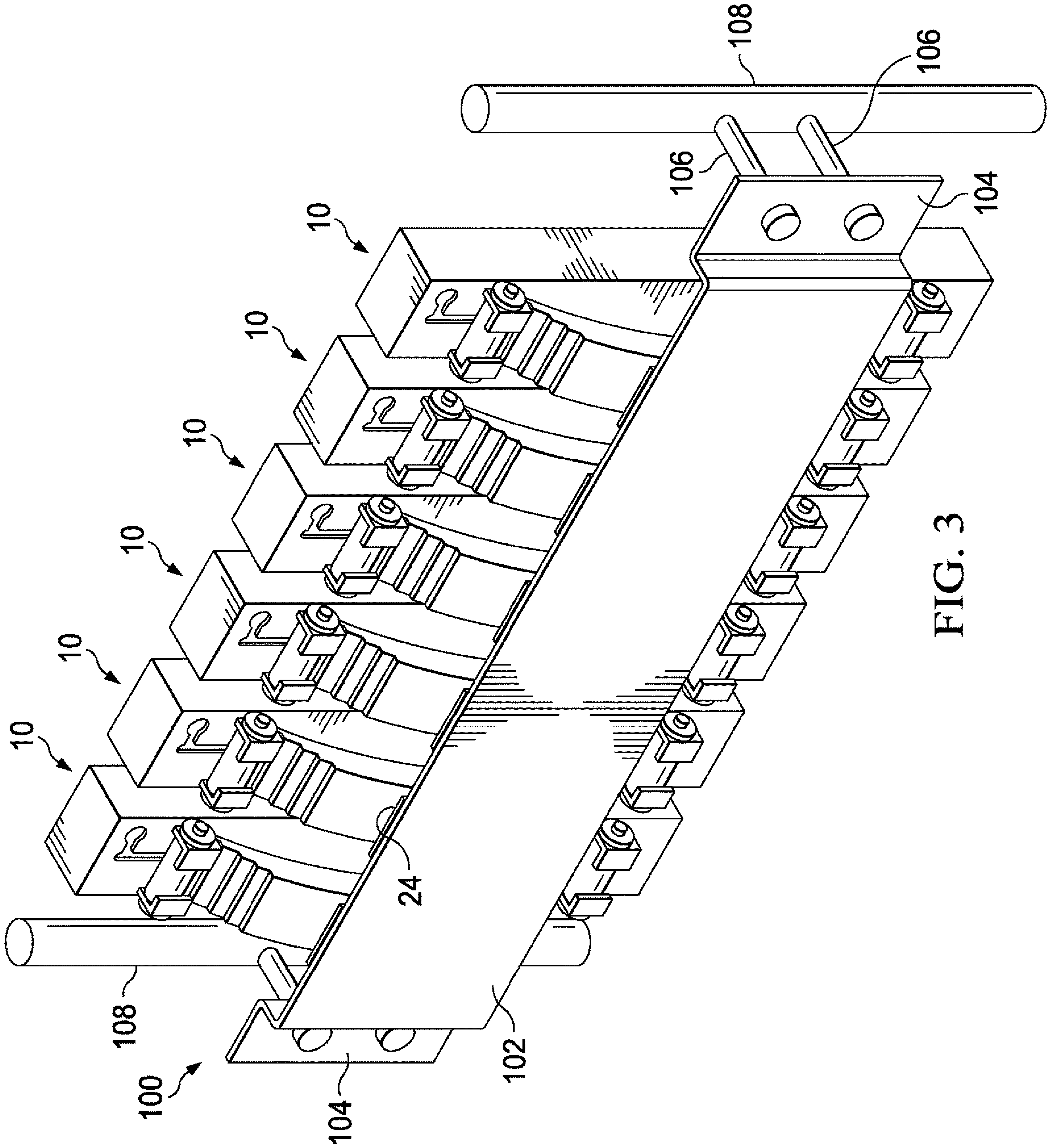

FIG. 3

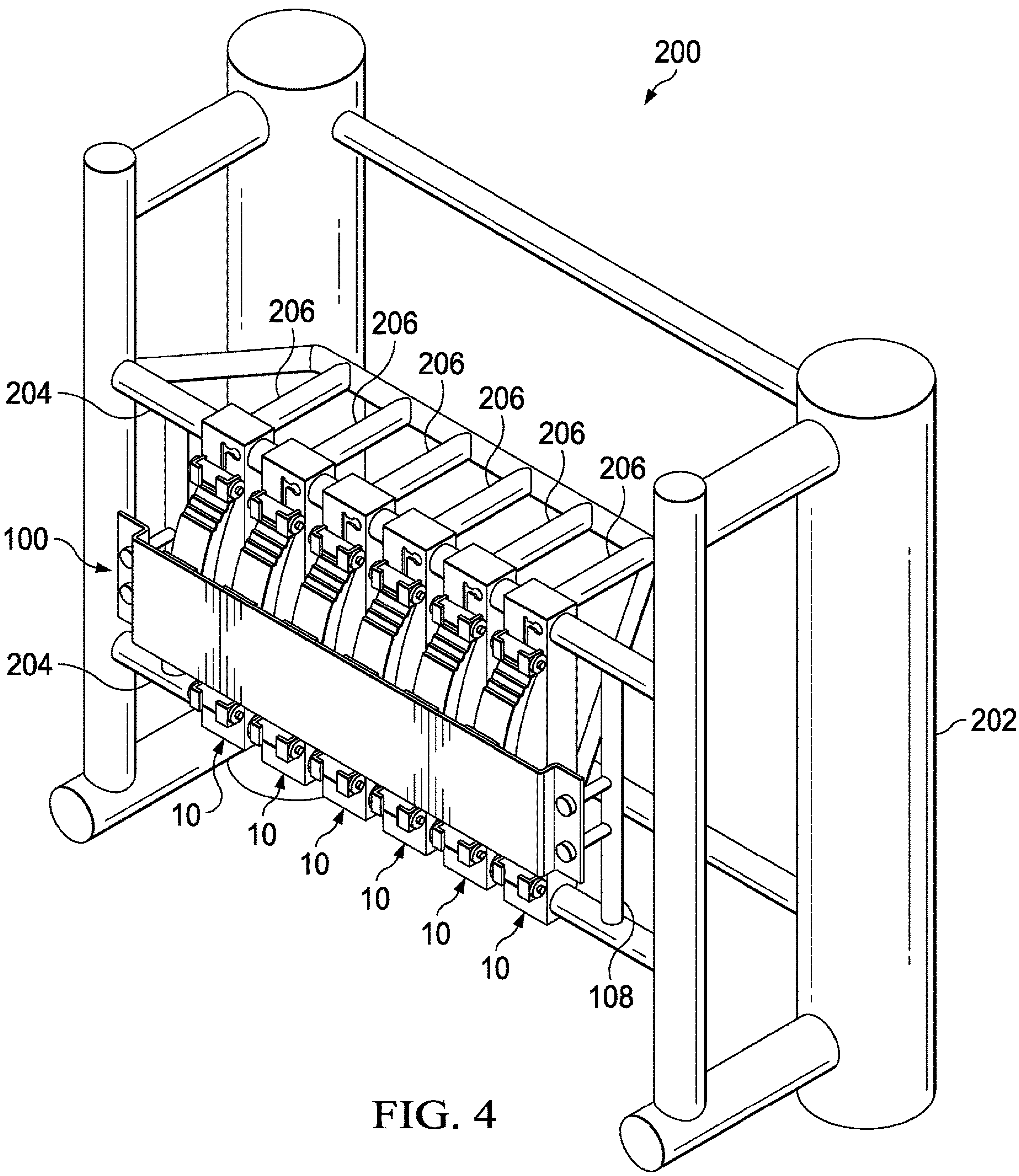

FIG. 4

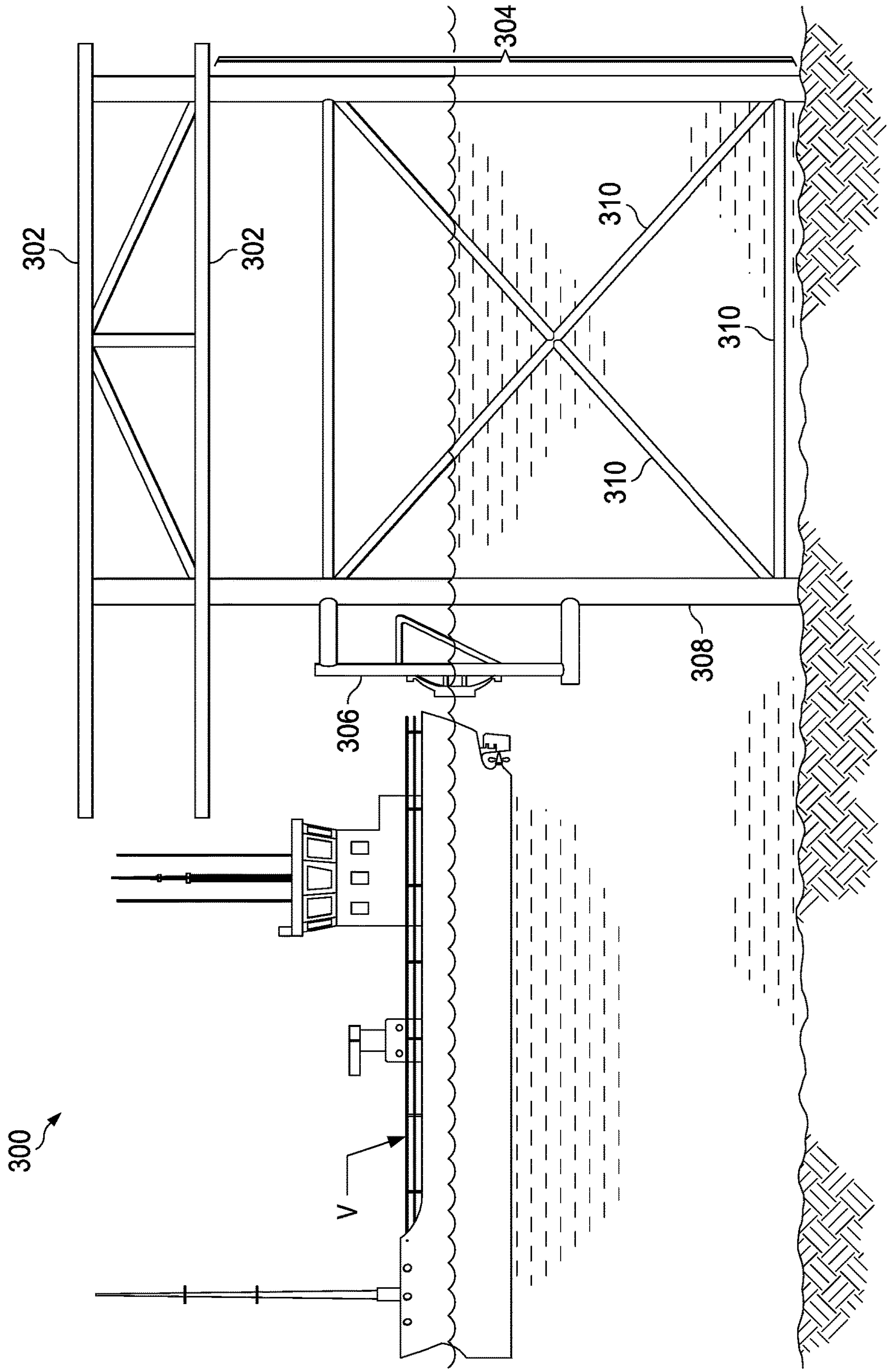

FIG. 5A

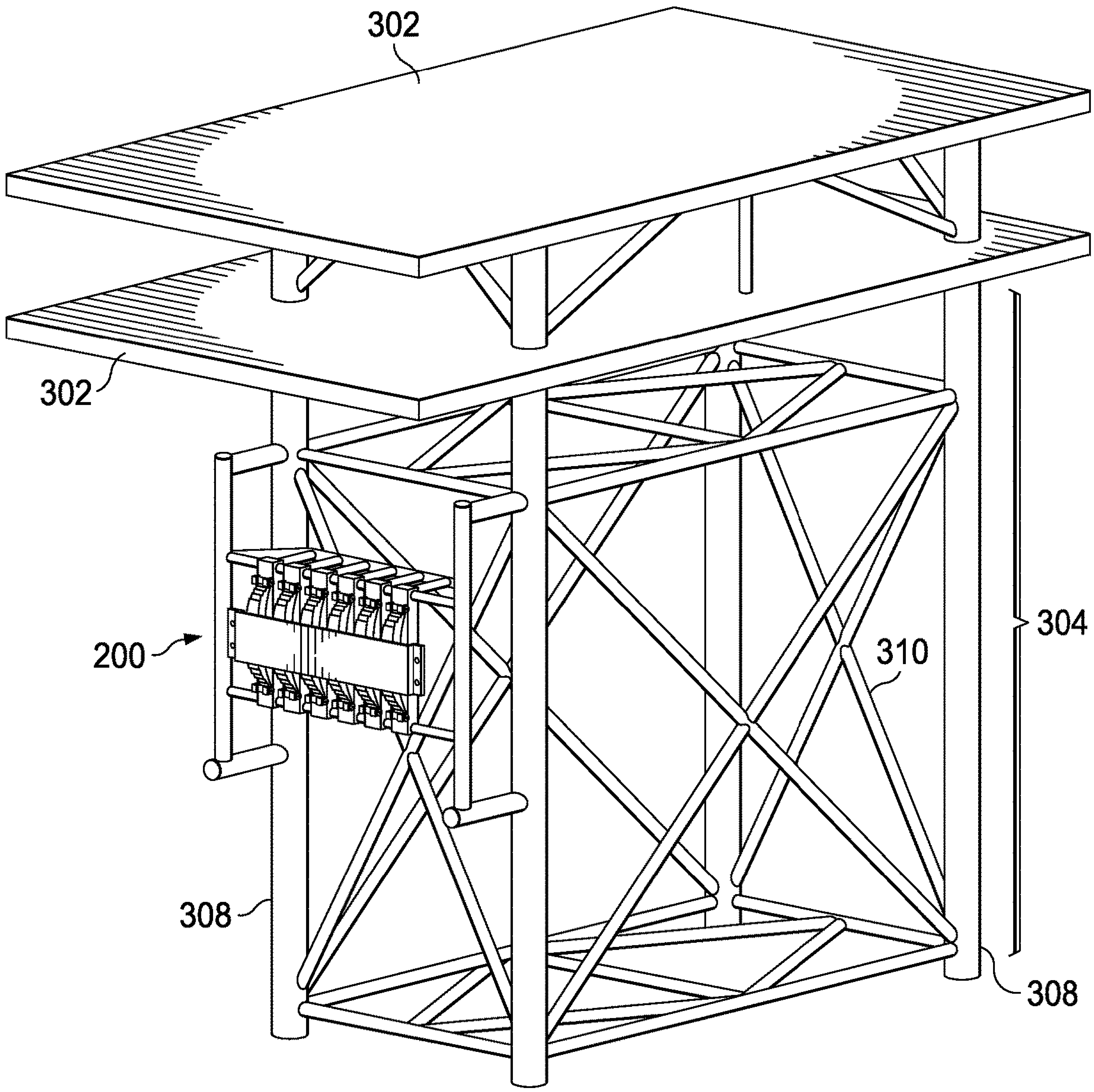

FIG. 5B

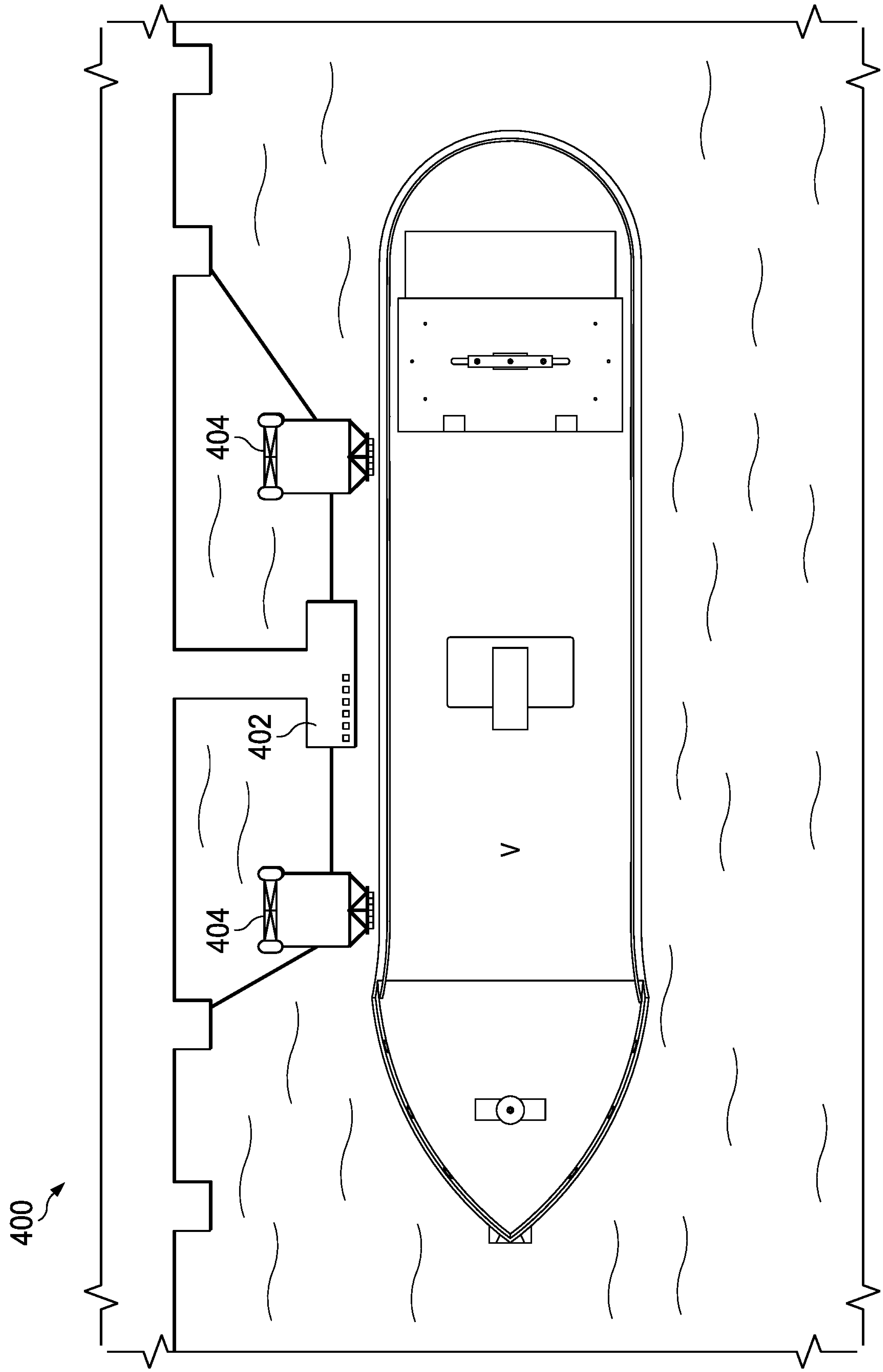

FIG. 6A

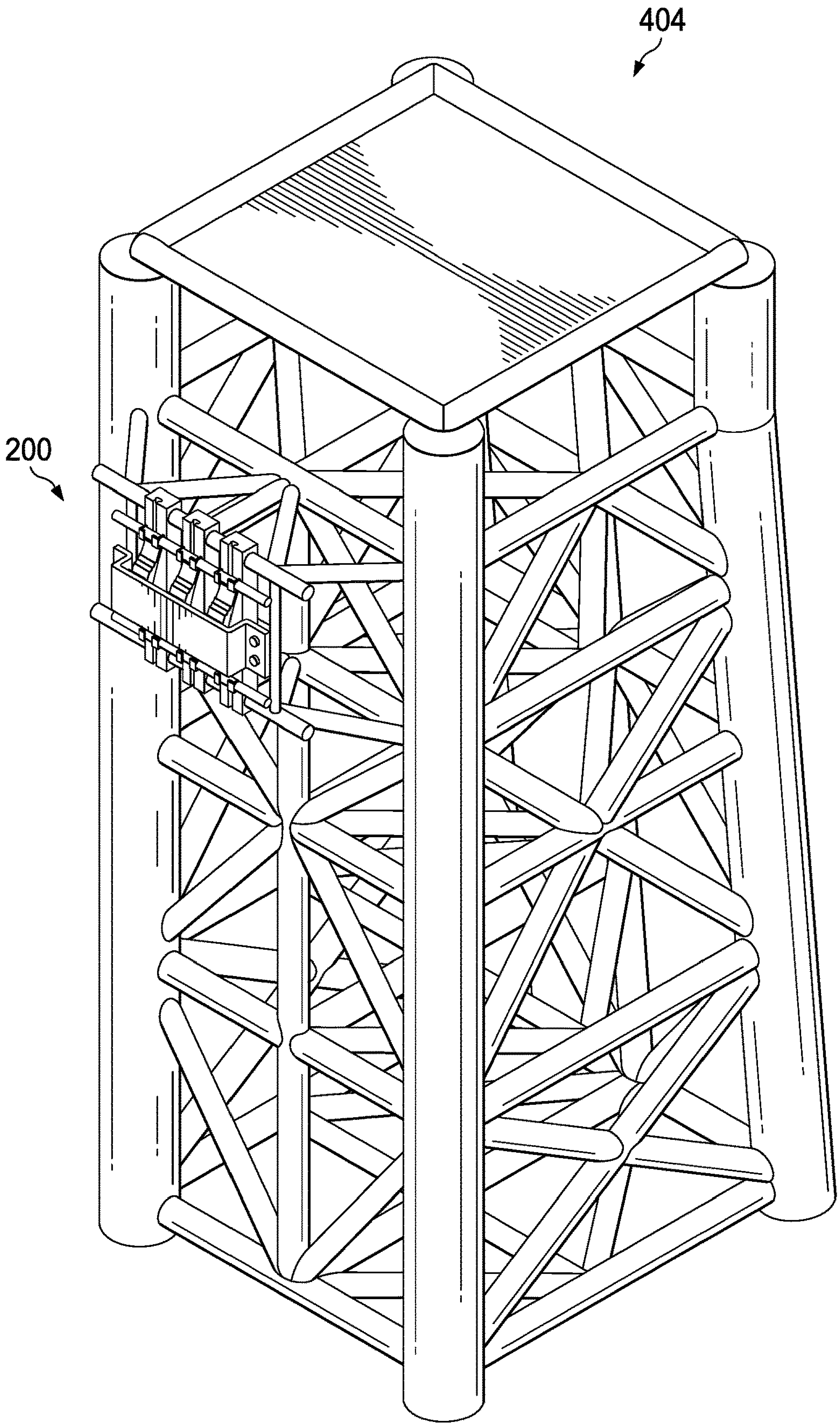

FIG. 6B

RESILIENT BUMPER AND BUMPER SYSTEM

TECHNICAL FIELD

This specification relates to resilient bumpers and bumper systems.

BACKGROUND

Bumpers are used to absorb shock and prevent damage when two objects collide. In some cases, the bumper is mounted to a moving object. In other cases, the bumper is mounted to a stationary object. A bumper system can include multiple individual bumpers, for example, attached to a structure, such as a pier or a building. On impact, the bumper deforms to absorb a portion of the impact energy. In some cases, this deformation is substantially irreversible, for example, for car bumpers. In contrast, resilient bumpers return substantially to their original state and are designed for repeated impact.

SUMMARY

In general, this disclosure relates to a resilient bumper and bumper systems.

In one aspect, a resilient bumper includes an arc-shaped spring member that extends from a first end to a second end along a spring axis and includes an impact surface arranged between the first and second ends; and a support member that includes an attachment interface that extends in parallel to the spring axis of the spring member and is configured to releasably engage the first and second ends of the spring member.

Implementations may include one or more of the following features.

In some implementations, at least one of the first and second ends of the spring member are moveably mounted to the attachment interface, wherein a deflection of the spring member increases a distance between the first and second ends of the spring member along the spring axis.

In some implementations, the spring member includes a leaf spring including a spring steel, a fiber-reinforced material, a resin, a composite material, or a combination thereof. For example, the spring member can include a stacked leaf spring that includes a stack of arc-shaped spring leaves and one or more clamps to clamp the stack of spring leaves. In some implementations, each spring leaf includes a spring steel, a fiber-reinforced material, a resin, a composite material, or a combination thereof. In some implementations, the stacked leaf spring further including a flat bumper plate that forms the impact surface, wherein the clamp presses the bumper plate against the stack of spring leaves.

In some implementations, the first end of the spring member includes a first pair of rollers rotatably mounted to the first end of the spring member, and the second end of the spring member includes a second pair of rollers rotatably mounted to the second end of the spring member, wherein the first and second pair of rollers are configured to roll along a surface of the support member as the first and second ends move along the attachment interface.

In some implementations, the first end of the spring member includes a first sliding pin and the second end of the spring member includes a second sliding pin, the attachment interface includes a slot formed in a surface of the support member and configured to receive a shaft portion of each of the first and second sliding pins, and the first and second sliding pin each include a head portion connected to the shaft portion and having an outer diameter larger than a width of an opening of the slot.

In some implementations, the attachment interface includes one or more insertion openings that are sized to accommodate the head portion of the first and second sliding pins and communicate with the slot. In some implementations, the one or more insertion openings are offset laterally to the spring axis and connected to the slot by a respective connection portion.

In some implementations, the slot includes a first slot segment configured to receive the shaft portion of the first sliding pin and a second slot segment configured to receive the shaft portion of the second sliding pin, wherein the first and second slot segments are separate from one another.

In some implementations, the slot includes a hook portion that supports the first or the second sliding pin at a fixed vertical position along the spring axis.

In some implementations, the first and second pairs of rollers are received within the support member and configured to travel along an inner surface of the support member, wherein the attachment interface includes an opening through which the spring member extends.

In some implementations, the spring member includes a composite material and one or more optic fiber sensors embedded in the composite material, wherein the one or more optic fiber sensors are configured to detect the a load as the spring member deflects.

In some implementations, the support member includes one or more mounting holes for mounting the support member.

In another aspect, a bumper system includes a plurality of resilient bumpers, each resilient bumper including an arc-shaped spring member that extends from a first end to a second end along a spring axis and includes an impact surface arranged between the first and second ends, and a support member that includes an attachment interface that extends in parallel to the spring axis of the spring member and is configured to releasably engage the first and second ends of the spring member; and a frame to which the support member of each of the plurality of resilient bumpers is connected, such that the resilient bumpers are aligned along a frame axis substantially transverse to the spring axis of each resilient bumper.

Implementations may include one or more of the following features.

In some implementations, at least one of the first and second ends of the spring member are moveably mounted to the attachment interface, wherein a deflection of the spring member increases a distance between the first and second ends of the spring member along the spring axis.

In some implementations, the bumper system includes a load panel that extends along the frame axis and covers the resilient bumpers, wherein each of the spring members of the plurality of resilient bumpers includes a flat bumper configured to engage the load panel.

In some implementations, each of the spring members includes a composite material and one or more optic fiber sensors embedded in the composite material, wherein the one or more optic fiber sensors are configured to detect the a load as the spring member.

In a further aspect, a marine structure includes a plurality of resilient bumpers, each resilient bumper including an arc-shaped spring member that extends from a first end to a second end along a spring axis and includes an impact surface arranged between the first and second ends, and a support member that includes an attachment interface that extends in parallel to the spring axis of the spring member and is configured to releasably engage the first and second ends of the spring member; and a frame to which the support member of each of the plurality of resilient bumpers is connected, such that the resilient bumpers are aligned along a frame axis substantially transverse to the spring axis of each resilient bumper, wherein the frame is configured to rest on the seabed.

The details of one or more implementations of the subject matter described in this specification are set forth in the accompanying drawings and the detailed description. Other features, aspects, and advantages of the subject matter will become apparent from the description, the drawings, and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A shows a front perspective view of a resilient bumper according to one implementation.

FIG. **1**B shows a rear perspective view of the resilient bumper of FIG. **1**A.

FIG. **2**A to **2**C shows a rear view of different attachment interfaces.

FIG. **3** shows a front perspective view of a plurality of resilient bumpers according to one implementation.

FIG. **4** shows the resilient bumpers of FIG. **3** integrated into a bumper system according to an implementation.

FIG. **5**A is a schematic illustration of an offshore platform and an implementation of a bumper system from the side.

FIG. **5**B shows a perspective view of the offshore platform in FIG. **5**A.

FIG. **6**A is a schematic illustration of a marine terminal that includes two breasting dolphins.

FIG. **6**B shows a perspective view of one of the breasting dolphins in FIG. **6**A.

DETAILED DESCRIPTION

Referring to FIGS. **1**A and **1**B, an implementation of a resilient bumper **10** is shown. The resilient bumper **10** comprises a spring member **12** and a support member **14**. The spring member **12** is arc-shaped and includes an impact surface **15** at a crown of the arc. The impact surface **15** is the surface that comes into contact with, i.e., bumps or is bumped into, an object external to the bumper and deflects the spring member **12**. For example, the impact surface **15** can be equidistant to the spring member's first and second ends **16**, **18**. The spring member **12** extends along a spring axis S between a first end **16** and a second end **18**. The support member **14** comprises an attachment interface or track **17** that extends in parallel to the spring axis S of the spring member **12** (FIG. **1**B). The attachment interface is configured to releasably engage the first and second ends of the spring member to mount the spring member **12** to the support member **14**. In FIGS. **1**A and **1**B, the first and second ends **16**, **18** of the spring member **12** are moveably mounted to the track **17** of the support member **14** such that a deflection of the spring member transverse to the spring axis S moves the first and the second ends **16**, **18** relative to the support member **14**.

In some cases, the arc-shaped spring member **12** can comprise a leaf spring. A leaf spring is a curved strip of resilient material that is substantially longer than it is wide. In some cases, the arc-shaped spring member **12** includes a stacked leaf spring that comprises a stack of arc-shaped spring leaves **20** and one or more clamps **22** to clamp the stack of spring leaves **20**. For example, friction between the individual spring leaves **20** can provide a damping action as an object collides against the spring member **12**. Instead of the clamp **22**, the spring member **12** can also comprise U-bolts that maintain friction among the stack of spring leaves **20**.

As illustrated in FIGS. **1**A and **1**B, the leaves **20** of the stacked leaf spring become progressively shorter along the spring axis S. However, the stacked leaf spring can also include leaves that have substantially the same length. The illustrated stacked leaf spring includes five individual spring leaves **20**. However, in other implementations, the number of leaves **20** can differ. As previously mentioned, the leaf spring can include a single leaf. Other implementations can include fewer or greater than five leaves depending on the forces to be absorbed by the bumper **10**. In some implementations, all of the springs leaves **20** are made of the same material. Example materials for spring leaves include spring steel, a fiber-reinforced material, a resin, a composite material, or a combination thereof. The spring leaves **20** can be formed by 3D printing. In some cases, a stacked leaf spring can include spring leaves **20** made of different materials.

In addition to the curved spring leaves **20**, some stacked leaf springs include a flat bumper plate **24** arranged on the topmost leaf **20**. The bumper plate **24** includes an outer surface **26** that forms the bumper's impact surface **15**. For example, if the bumper plate **24** and the spring leaves **20** are viewed from the side, the center line of the flat outer surface **26** and the respective spring leaves meet at the crown of the spring leaves **20**. In some implementations, the bumper plate **24** can also include a curved inner surface that is shaped to mate with the curved spring leaves **20**. Accordingly, the bumper plate **24** can include two wedge portions **28** that transition between the flat outer surface **26** and the curved inner surface. As illustrated, the length of the bumper plate **24** along the spring axis S amounts to roughly half of the length of the spring member **12**. In some cases, the ratio of the length of the bumper plate **24** to the length of the spring member **12** can be greater or smaller, e.g., ⅓ or ⅔. Although the bumper plate **24** forms the impact surface **15** in the illustrated implementation, other implementations do not necessarily include a bumper plate **24**. Instead, the impact surface can be formed by the outer surface of the topmost leaf **20** at the crown of the arc, for example.

The first end **16** of the spring member **12** can include a first pair of rollers **30** that are rotatably mounted to the first end **16** of the spring member **12**. The second end **18** of the spring member **12** can include a second pair of rollers **32** that are rotatably mounted to the second end **18** of the spring member **12**. The first and second pair of rollers **30**, **32** are configured to roll along a surface **34** of the support member **14** as the first and second ends **16**, **18** of the spring member **12** move with respect to the support member **14**. In the illustrated implementation, the first and second pair of rollers **30**, **32** roll along the top or outer surface **34** of the support member **14**. For example, the spring member **12** can include a loop **36** at each end. A bolt **38** can extend through the loop, transverse to the spring axis. A spacer **40** and each of the rollers **30**, **32** can be rotatably mounted on the bolt **38**. The loop **36** can be formed integrally by one of the spring leaves **20**. Instead of a common bolt **38**, each roller can also be mounted by a separate bolt or pin.

In some implementations, the first and second ends **16**, **18** of the spring member **12** are moveably mounted to a track **17** of the support member **14** to connect the spring member **12** and the support member **14**. The support member's track **17** can have various configurations that engage the first and second ends **16**, **18** of the spring member **12** in different ways. For example, the first end **16** of the spring member **12** can include a first sliding pin **42** and the second end **18** of the spring member **12** can include a second sliding pin **44** (FIG. **1**B). The track **17** can comprise a slot formed in the surface **34** of the support member **14** that is configured to receive a shaft portion of each of the first and second sliding pins **42**, **44**. The first and second sliding pin **42**, **44** can each comprise a head portion that is connected to the shaft portion and has an outer diameter larger than a width of an opening of the slot. The track **17** can also include one or more insertion openings **46** that are sized to accommodate the head portion of the first and second sliding pins **42**, **44** and communicate with the slot. For example, the slot and the insertion openings **46** can form a keyhole shape. In some cases, the insertion opening **46** is directly connected to the slot and lies along the spring axis S, as shown at the bottom of FIG. **1**B. Alternatively, the insertion opening **46** can be offset from the spring axis S and connected to the slot by a connection portion **48**, as shown at the top of FIG. **1**B. For example, an offset insertion opening **46** may prevent the spring member **12** from disconnecting from the support member **14**.

In some cases, the slot can include a first slot segment **50** that receives the shaft portion of the first sliding pin **42** and a second slot segment **52** distinct from the first slot segment **50** that receives the shaft portion of the second sliding pin **44**. In such cases, one of the slot segments **50**, **52** can include a hook portion at one end that supports the first or the second sliding pin **42**, **44** at a fixed vertical position along the spring axis S. In FIG. **1**B, the first sliding pin **42** is located in the hook portion of the first slot segment **50** to hang the spring member **12** at its first end **16**. Alternatively, the spring member **12** can be supported in a similar manner by its second end **18**. Although the bumper **10** is illustrated with two slot segments **50**, other implementations can include one continuous slot.

The bumper **10** of FIGS. **1**A and **1**B can be assembled by inserting the head portion second sliding pin **44** into the second slot segment's insertion opening **46**. The spring member **12** is pivoted about the second sliding pin **42** so that the head portion of the first sliding pin **42** enters the first slot segment's insertion opening **46**. The first sliding pin **42** is then moved along the connection portion **48** and into the first slot segment **50**. Thus, the bumper **10** of FIGS. **1**A and **1**B can be easily assembled largely without the use of tools.

The assembled resilient bumper **10** can be mounted by the support member **14** to another structure and used to absorb shock and prevent damage to the structure, as explained in more detail in reference to FIGS. **5**A, **5**B, **6**A, and **6**B. For this purpose, the support member **14** can include one or more mounting holes **54** (FIG. **1**A). An object that collides with the bumper **10** will generally make contact with the impact surface **15** formed, for example, by the bumper plate **24**. The colliding object causes the spring member **12** to deflect inward towards the support member **14** in a direction transverse to the spring axis S, in the direction indicated by the arrow D in FIG. **1**B.

In some implementations, the first and second ends **16**, **18** of the spring member **12** are not fixed in place, and one or both ends **16**, **18** can move in response to the deflection of the spring member **12**. For example, referring to FIG. **1**B, a collision may cause the second sliding pin **44** to move downward along the second slot segment **52** while the first sliding pin **42** remains in the hook portion illustrated in FIG. **1**B. However, since the first sliding pin **42** is not fixedly attached to the first slot segment **50**, a subsequent collision may cause the first sliding pin **42** to move upward along the first slot segment **50** while the second sliding pin **44** moves along the second slot segment **52**. In both cases, since the first and second ends **16**, **18** are moveably mounted to the support member **14**, the deflection of the spring member **12** causes the first and second ends **18** to move apart and increase a distance between the first and second ends **16**, **18** along the spring axis S. Since the illustrated bumper **10** allows the spring member **12** and its ends **16**, **18** to move relative to the support member **14**, the bumper **10** may be less prone to mechanical failure at the connection points between the spring member **12** and the support member **14** than, e.g., bolts or welded connections.

In FIG. **2**A to **2**C, different configurations of attachment interfaces **17***a*-**17***c* that form alternatives to track **17** in FIGS. **1**A and **1**B. FIG. **2**A shows an attachment interface or track **17***a* with a first slot segment **50***a* and a second slot segment **52***a* that moveably mount the first and second ends of the spring member to the support member. The first slot segment **50***a* corresponds to the first slot segment **50** in FIGS. **1**A and **1**B. The second slot segment **52***a* has the same design as the first slot segment **50***a*. In other words, the second slot segment **52***a* includes an insertion opening **46***a* that is sized to accommodate the head portion of a sliding pin. The insertion opening **46***a* is connected to the slot by a connection portion **48***a*. Since the first and second ends of the spring member are not fixed in place, one or both ends of the spring member can move in response to the deflection of the spring member to absorb substantial levels of impact energy.

FIG. **2**B shows an attachment interface or track **17***b* with an attachment section **51***b* and a slot segment **52***b*. The slot segment **52***b* is similar to the slot segments **50***a*, **52***a* in FIG. **2**A and allows the second end of the spring member to move along the spring axis S. In contrast, the attachment section **51***b* includes an insertion opening **46***b* that is connected to a hook portion **53***b* that mounts the first end of the spring member to the support member at a fixed position along the spring axis S. Since one end of the spring member is fixed in place, only the end of the spring member mounted to the slot segment **52***b* can move in response to the deflection of the spring member. Thus, the track **17***b* of FIG. **2**B is designed to absorb a moderate amount of impact energy, i.e., less impact energy than the track **17***a* of FIG. **2**A. Although the track **17***b* is shown with the attachment section **51***b* at the top and the slot segment **52***b* at the bottom, their positions may be reversed.

FIG. **2**C shows an attachment interface **17***c* that includes two attachment sections **51***c* that correspond to the attachment section **51***b* in FIG. **2**B. Each attachment section **51***c* includes an insertion opening **46***c* that is connected to a hook portion **53***c* that mounts the first end of the spring member to the support member at a fixed position along the spring axis S. Thus the attachment interface **17***c* is configured to releasably engage the first and second ends of the spring member to mount the spring member to the support member, but the ends of the spring member are not moveable relative to the support member **14**. Accordingly, the attachment interface **17***c* is designed to absorb the smallest amount of impact energy out of attachment interfaces **17***a*-**17***c*. In this implementation, the spring member includes a suitably elastic material that allows the spring member to attach to the support member and deflect upon impact of the load.

In some implementations, the spring member **12** can include a composite material and one or more optic fiber sensors embedded in the composite material. The optic fiber sensors can be used to detect the extent to which the spring member **12** deflects, and thus the load absorbed by the bumper **10**. Such information can be processed using machine learning techniques to predict, for example, maintenance intervals.

In the implementation illustrated in FIGS. **1**A and **1**B, the support member **14** has a rectangular cross section **56**, the first and second sliding pins **42**, **44** are positioned inside of the cross-section **56** via the slot segments **50**, **52**. In other implementations, the track does not include a slot or slot segments. For example, the support member **14** can form a U-shaped track, with the rollers **30**, **32** received within the U-shaped cross-section. The arc-shaped portion of the spring member **12** can protrude from the opening of the U-shape and the first and second ends **16**, **18** can still move apart on deflection in the previously described manner. An implementation with a U-shaped track may not necessarily include first and second sliding pins **42**, **44**.

Other implementations may not necessarily include rollers **30**, **32** that move across the outer surface of the support member **14**. For example, the support member **14** can have a circular, elliptical, or hexagonal shape that makes such rollers **30**, **32** impractical. In this case, the first and second ends **16**, **18** can be connected to a slot or slot segments by sliding pins that are similar to first and second sliding pins **42**, **44**. Although the first and second sliding pins **42**, **44** are relatively small in comparison to the size of the loops **36**, the size shown in the drawing is not necessarily representative.

Thus, the resilient bumper of the present disclosure acts as an elastic machine that undergoes deflection under the application of large loads and is designed to regain its original shape once the load is removed. As such, it serves as a shock absorber that reduces the amount of energy transmitted to the structure connected to the bumper by storing most of the impact energy as potential energy upon deflection during loading. The bumper can be installed individually or in series and thus provides a flexible and modular bumper design for different types of structures.

Referring now to FIG. **3**, a plurality of resilient bumpers **10** is shown. The bumpers **10** are arranged at the same height and covered by a common load plate **100**. More specifically, the load plate **100** includes a plate portion **102** that transfers loads to the impact surface **15** of each resilient bumper **10**. In other words, the plate portion **102** forms a common impact surface for the plurality of bumpers **10**. For example, a rear surface of the plate portion **102** includes rectangular recesses that each engage a bumper plate **24** of a respective bumper **10**. Since the load plate **100** is attached to each of the bumpers **10**, the load from a colliding object can be evenly distributed across the bumpers **10**. For example, in the illustrated implementation, the plate portion **102** has approximately the same height as and covers the entire bumper plate **24** of each spring member **12**. However, the plate portion **102** is not necessarily attached to the individual bumpers **10**. In some cases, the plate portion **102** may merely rest upon the spring members **12** of the plurality of bumpers **10** instead of being attached to the impact surfaces of the individual bumpers **10**.

The load plate **100** includes two mounting sections **104** for mounting the plate portion **102**. For example, each mounting section **104** can be bent away from the plate portion **102** to increase the overall strength of the load plate **100**. Each mounting section **104** can be mounted to a pair of rods **106** that are connected to a mounting beam **108**. When an object collides with the plate portion **102**, the plate portion **102** can transfer force to each spring member **12** via its impact surface and cause the spring member **12** to deflect. At the same time, the mounting sections **104** can be configured to slide along the rods **106** such that the load plate **100** moves with the spring members **12** of the bumpers **10**. In other cases, the mounting sections **104** of the plate portion **102** are fixed to the frame. In this case, the plate portion **102** can deflect inward towards the spring members **12**.

FIG. **4** is a perspective view of a bumper system **200**. In general, a bumper system **200** includes a plurality of bumpers **10** and a frame **202** to which the support member of each of the plurality of resilient bumpers is connected. The illustrated implementation of the bumper system **200** includes the optional load plate **100** shown in FIG. **3**. The frame **202** can be a freestanding structure, but it can also be integrated into a larger structure, as shown in FIGS. **5**A, **5**B, **6**A, and **6**B. For example, the frame **202** can include a pair of cross bars **204** that extend through the respective top and bottom mounting holes **54** in each support member **14**. An individual support **206** can be arranged transverse to the cross bar **204** behind each support member **14** to provide further structural integrity. The mounting beams **108** of the load plate **100** can also extend transversely to and between the pair of cross bars **204**.

In the illustrated implementation, the frame **202**, the support members **14**, and the mounting beams **108** can be assembled once to form a permanent structure. The plate portion **102** can be removed and the individual spring members **12** can be replaced. For example, if one of the spring members **12** breaks, the plate portion **102** can be removed and a new spring member **12** can be mounted to the corresponding support member **14** in the previously described manner. After the broken spring member **12** is replaced, the plate portion **102** of the load plate **100** can be reattached to the rods **106** and mounting beams **108** to restore the bumper system **200** to its working condition.

Although the implementations illustrated in FIGS. **3** and **4** include a load plate **100**, other implementations of the bumper system **200** can include a plurality of resilient bumpers **10** that are mounted to a frame **202** without a common load plate **100**. In some situations, it may be desirable that the spring members **12** deflect individually as opposed to the load being distributed across all of the spring members **12**.

Both in implementations with and without a load plate **100**, the spring members **12** can include optic fiber sensors that detect the deflection and load applied to the spring members **12**. Such information can be collected and aggregated for maintenance purposes or to ensure that the bumper system **200** has a sufficient number of bumpers **10** to absorb the loads that result when foreign objects collide with the bumper system **200**.

FIGS. **5**A, **5**B, **6**A, and **6**B show two examples of the bumper system **200** in use in a marine setting. More specifically, FIGS. **5**A and **5**B show an offshore platform **300** that includes one or more decks **302**, a support structure **304**, and a boat landing **306**. The decks **302** are arranged above sea level and support equipment that is omitted from the drawing. The support structure **304** comprises welded steel tubular members that form beams and columns that support the decks **302**. In the illustrated example, four columns **308** extend from the seabed to the decks **302** and are connected by several reinforcing beams **310**. The boat landing **306** is arranged at sea level and is designed to protect the offshore platform **300** from collision with ships. For this purpose, the boat landing **306** includes a bumper system **200**. The bumper system's frame **202** and the platform's support structure **304** can share common components, such as the columns **308**. Since the bumper system **200** protects the offshore platform **300** from collisions with ships and other vessels, smaller tubular members can be used to form the support structure

304. In addition to preventing general damage from vessels, the bumper system 200 may even allow a larger type of vessel to land at the boat landing 306 than the offshore platform 300 would otherwise be able to accommodate.

FIGS. 6A and 6B show a further implementation in which the bumper system 200 of the present disclosure is incorporated into a marine terminal. A marine terminal 400 can include a pier 402 and one or more breasting dolphins 404. A breasting dolphin is a marine structure for berthing and mooring a vessel V along the pier 402. The purpose of a breasting dolphin 404 is to absorb impact from the vessel V and to prevent the vessel from coming into contact with the pier 402. By absorbing some of the berthing loads, breasting dolphins allow large vessels to berth at much smaller pier structures. Breasting dolphins 404 can also serve as mooring points that prevent the vessel V from moving in a longitudinal direction.

Similarly to the boat landing in FIGS. 5A and 5B, the breasting dolphin 404 comprises a bumper system 200 positioned at sea level, i.e., at the location at which the vessel V is likely to come into contact with the breasting dolphin 404. Unlike the implementations shown in FIGS. 3, 4, 5A, and 5B, the bumper system 200 of FIGS. 6A and 6B only has three resilient bumpers. However, depending on the application, the bumper system 200 for the breasting dolphin 404 can be adapted to include a larger number of resilient bumpers.

In addition to the boat landing and the breasting dolphin shown in FIGS. 5A, 5B, 6A, and 6B, the resilient bumper 10 and the bumper system 200 can also be used in fixed jackets, floating systems, ports, and naval bases, for example. The resilient bumpers and the bumper system of the present disclosure can be flexibly adapted to a specific pier, structure, or vessel and do not depend on a large contact area along the longitudinal length of the vessel.

The above description is presented to enable any person skilled in the art to make and use the disclosed subject matter, and is provided in the context of one or more particular implementations. Various modifications to the disclosed implementations will be readily apparent to those skilled in the art, and the general principles defined in this disclosure may be applied to other implementations and applications without departing from scope of the disclosure. Thus, the present disclosure is not intended to be limited to the described or illustrated implementations, but is to be accorded the widest scope consistent with the principles and features disclosed in this disclosure.

What is claimed is:

1. A resilient bumper, comprising

an arc-shaped spring member that extends from a first end to a second end along a spring axis and comprises an impact surface arranged between the first and second ends; and

a support member that comprises an attachment interface that extends in parallel to the spring axis of the spring member and is configured to releasably engage the first and second ends of the spring member, wherein the attachment interface comprises a slot formed in a surface of the support member,

wherein at least one of the first and second ends of the spring member are moveably mounted to the attachment interface, wherein a deflection of the spring member increases a distance between the first and second ends of the spring member along the spring axis,

wherein the first end of the spring member comprises a first pair of rollers rotatably mounted to the first end of the spring member, and the second end of the spring member comprises a second pair of rollers rotatably mounted to the second end of the spring member, wherein the first and second pair of rollers are configured to roll along a surface of the support member as the first and second ends move along the attachment interface.

2. The bumper of claim 1, wherein the spring member comprises a leaf spring comprising a spring steel, a fiber-reinforced material, a resin, a composite material, or a combination thereof.

3. The bumper of claim 1, wherein the spring member comprises a stacked leaf spring that comprises a stack of arc-shaped spring leaves and one or more clamps to clamp the stack of spring leaves.

4. The bumper of claim 3, wherein each spring leaf comprises a spring steel, a fiber-reinforced material, a resin, a composite material, or a combination thereof.

5. The bumper of claim 3, the stacked leaf spring further comprising a flat bumper plate that forms the impact surface, wherein the clamp presses the bumper plate against the stack of spring leaves.

6. The bumper of claim 1,

wherein the first end of the spring member comprises a first sliding pin and the second end of the spring member comprises a second sliding pin,

wherein the slot is configured to receive a shaft portion of each of the first and second sliding pins, and

wherein the first and second sliding pin each comprise a head portion connected to the shaft portion and having an outer diameter larger than a width of an opening of the slot.

7. The bumper of claim 6, wherein the attachment interface comprises one or more insertion openings that are sized to accommodate the head portion of the first and second sliding pins and communicate with the slot.

8. The bumper of claim 7, wherein the one or more insertion openings are offset laterally to the spring axis and connected to the slot by a respective connection portion.

9. The bumper of claim 6, wherein the slot comprises a first slot segment configured to receive the shaft portion of the first sliding pin and a second slot segment configured to receive the shaft portion of the second sliding pin, wherein the first and second slot segments are separate from one another.

10. The bumper of claim 6, wherein the slot comprises a hook portion that supports the first or the second sliding pin at a fixed vertical position along the spring axis.

11. The bumper of claim 1, wherein the first and second pairs of rollers are received within the support member and configured to travel along an inner surface of the support member, wherein the attachment interface comprises an opening through which the spring member extends.

12. The bumper of claim 1, wherein the spring member comprises a composite material and one or more optic fiber sensors embedded in the composite material, wherein the one or more optic fiber sensors are configured to detect a load as the spring member deflects.

13. The bumper of claim 1, wherein the support member includes one or more mounting holes for mounting the support member.

14. A bumper system comprising:

a plurality of resilient bumpers, each resilient bumper comprising:

an arc-shaped spring member that extends from a first end to a second end along a spring axis and comprises an impact surface arranged between the first and second ends, and

a support member that comprises a slot formed in a surface of the support member and that extends in parallel to the spring axis of the spring member and is configured to releasably engage the first and second ends of the spring member; and

a frame to which the support member of each of the plurality of resilient bumpers is connected, such that the resilient bumpers are aligned along a frame axis substantially transverse to the spring axis of each resilient bumper,

wherein at least one of the first and second ends of the spring member are moveably mounted to the slot, wherein a deflection of the spring member increases a distance between the first and second ends of the spring member along the spring axis,

wherein the first end of the spring member comprises a first pair of rollers rotatably mounted to the first end of the spring member, and the second end of the spring member comprises a second pair of rollers rotatably mounted to the second end of the spring member, wherein the first and second pair of rollers are configured to roll along a surface of the support member as the first and second ends move along the slot.

15. The bumper system of claim **14**, further comprising a load panel that extends along the frame axis and covers the resilient bumpers, wherein each of the spring members of the plurality of resilient bumpers comprises a flat bumper plate configured to engage the load panel.

16. The bumper system of claim **14**, wherein each of the spring members comprises a composite material and one or more optic fiber sensors embedded in the composite material, wherein the one or more optic fiber sensors are configured to detect a load as the spring member deflects.

17. A marine structure comprising:

a plurality of resilient bumpers, each resilient bumper comprising

an arc-shaped spring member that extends from a first end to a second end along a spring axis and comprises an impact surface arranged between the first and second ends, and

a support member that comprises a slot formed in a surface of the support member and that extends in parallel to the spring axis of the spring member and is configured to releasably engage the first and second ends of the spring member; and

a frame to which the support member of each of the plurality of resilient bumpers is connected, such that the resilient bumpers are aligned along a frame axis substantially transverse to the spring axis of each resilient bumper, wherein the frame is configured to rest on the seabed,

wherein at least one of the first and second ends of the spring member are moveably mounted to the attachment interface, wherein a deflection of the spring member increases a distance between the first and second ends of the spring member along the spring axis,

wherein the first end of the spring member comprises a first pair of rollers rotatably mounted to the first end of the spring member, and the second end of the spring member comprises a second pair of rollers rotatably mounted to the second end of the spring member, wherein the first and second pair of rollers are configured to roll along a surface of the support member as the first and second ends move along the attachment interface.

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